Peter Baker, P.Eng.
Building Science Corporation

Exterior Cladding Attachment Research

Building America Expert Meeting

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
Building AMERICA U.S. Department of Energy

Overview

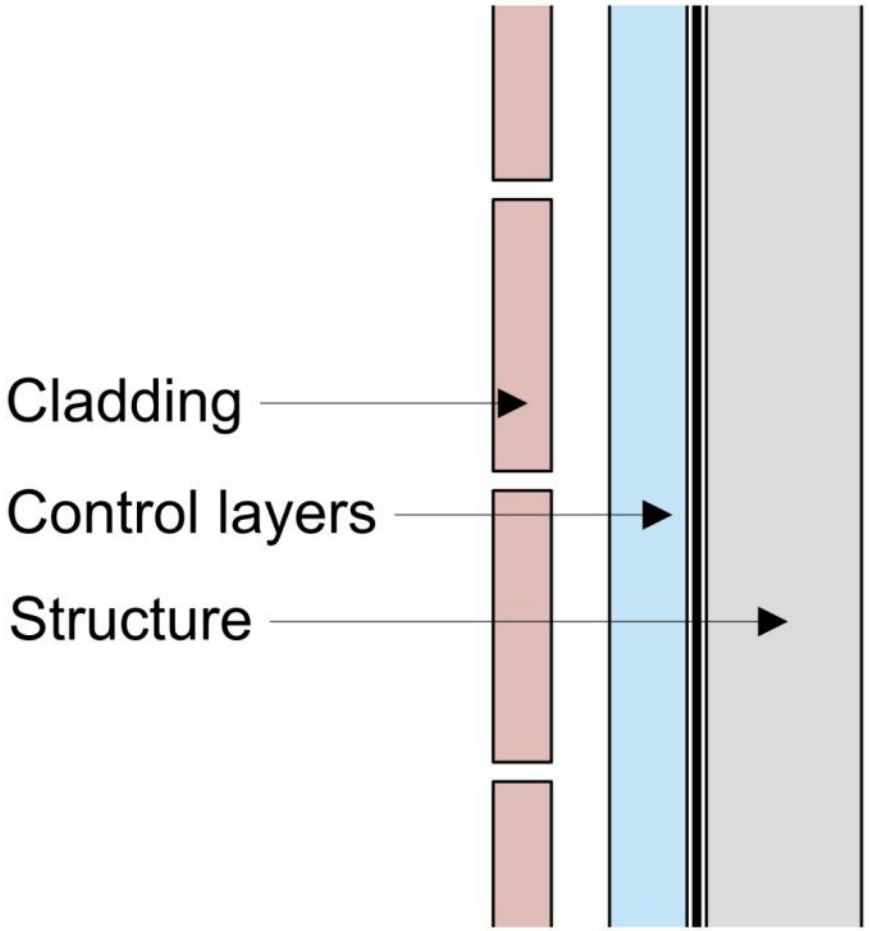
- Cladding Attachment Options
- Cladding Attachment Direct Through Exterior Insulation
- TO2 Building America Research (2011)
- TO3 Building America Research (2012)

Cladding Attachment Options

Exterior Rigid Insulation

- The “Perfect” Wall

- Increase overall thermal performance
- Minimize thermal bridges
- Minimize potential for air leakage condensation
- Improve air tightness?
- Improve rainwater management?

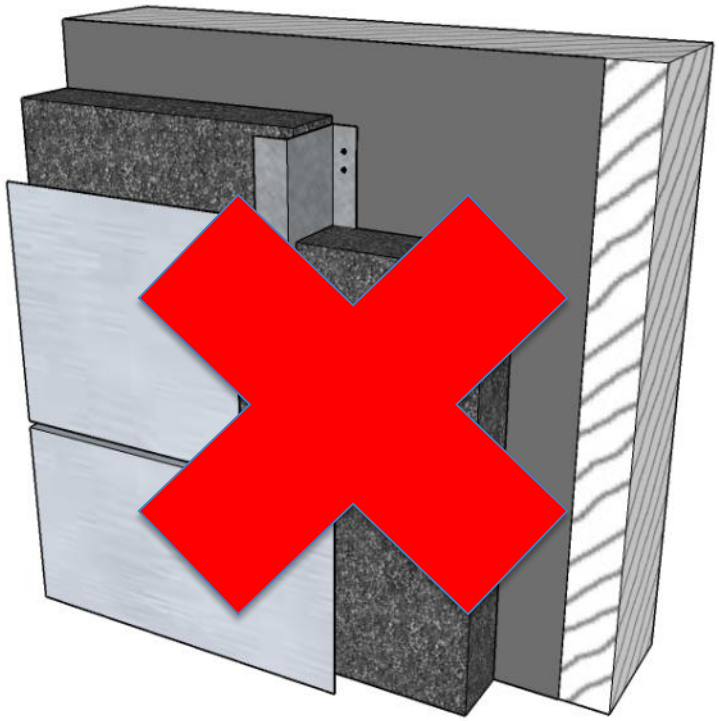


Cladding Attachment

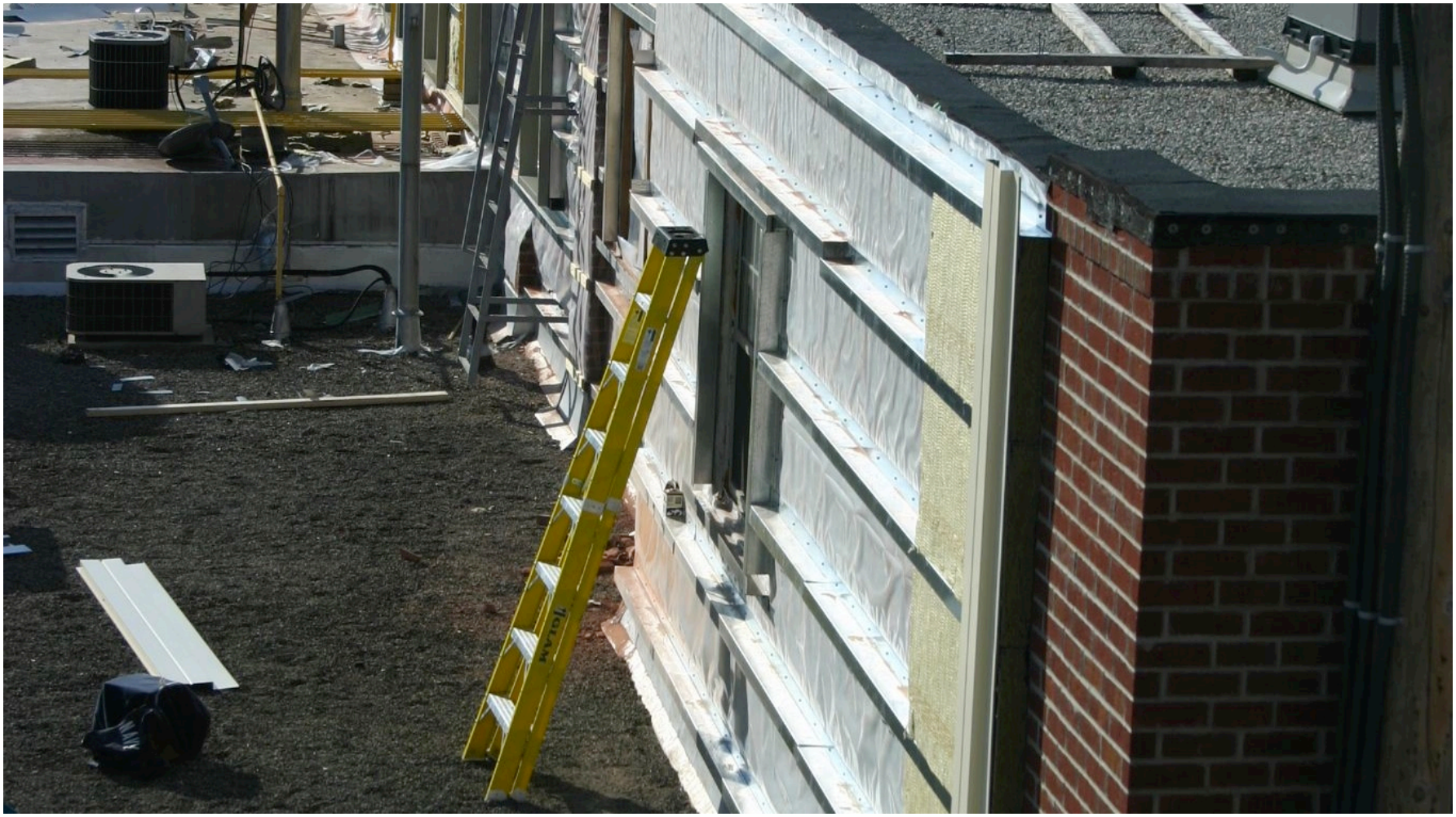
- For insulation 1.5” or less – direct attachment of cladding though insulation back to the structure is often practical
- For insulation greater than 1.5” – a secondary cladding support system is often needed.
  - Cladding support systems historically done poorly
  - Systems are getting better

Cladding Attachment

- Single “z-furring”
  - Poor thermal performance (steel stud wall on the exterior – why bother?)



Other Claddings

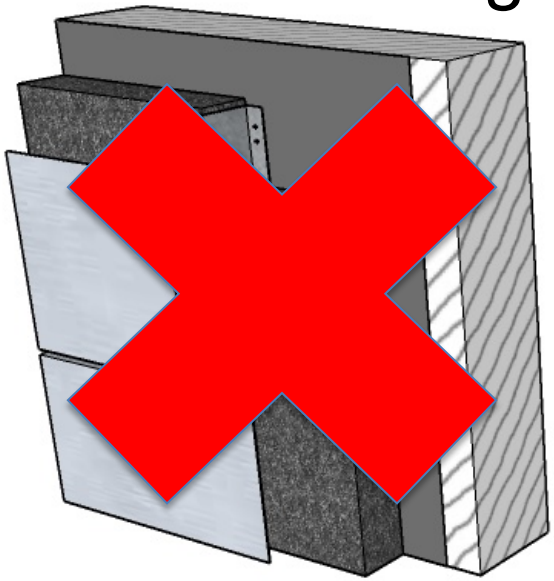


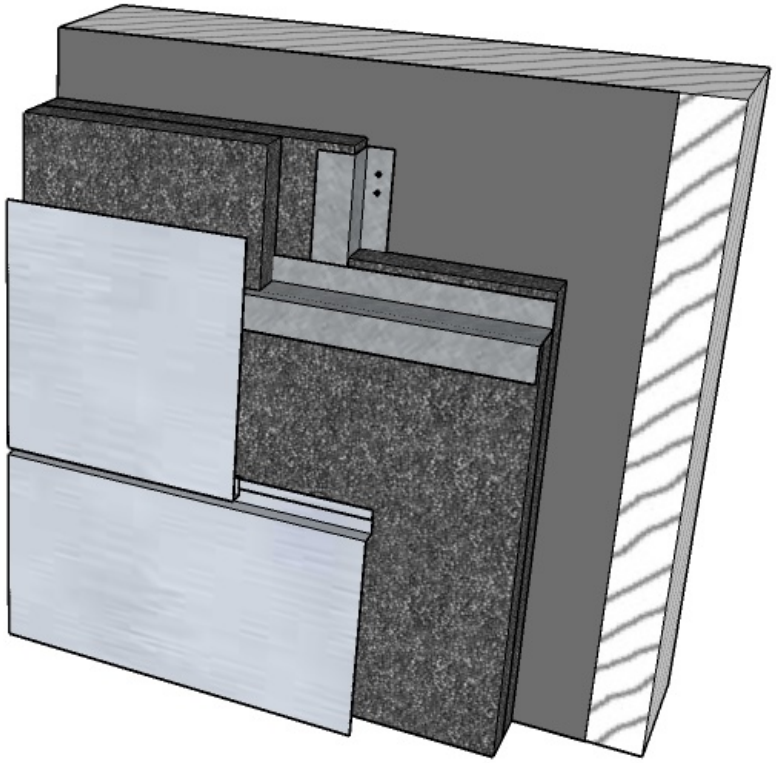
Cladding Attachment

- Single “z-furring”
- Double “z-furring”
  - Can be made to function reasonably well provided that two layers of insulation are used.
  - Often designed with first layer bridging insulation and second layer creating a gap behind the cladding = single “z-furring”

Cladding Attachment

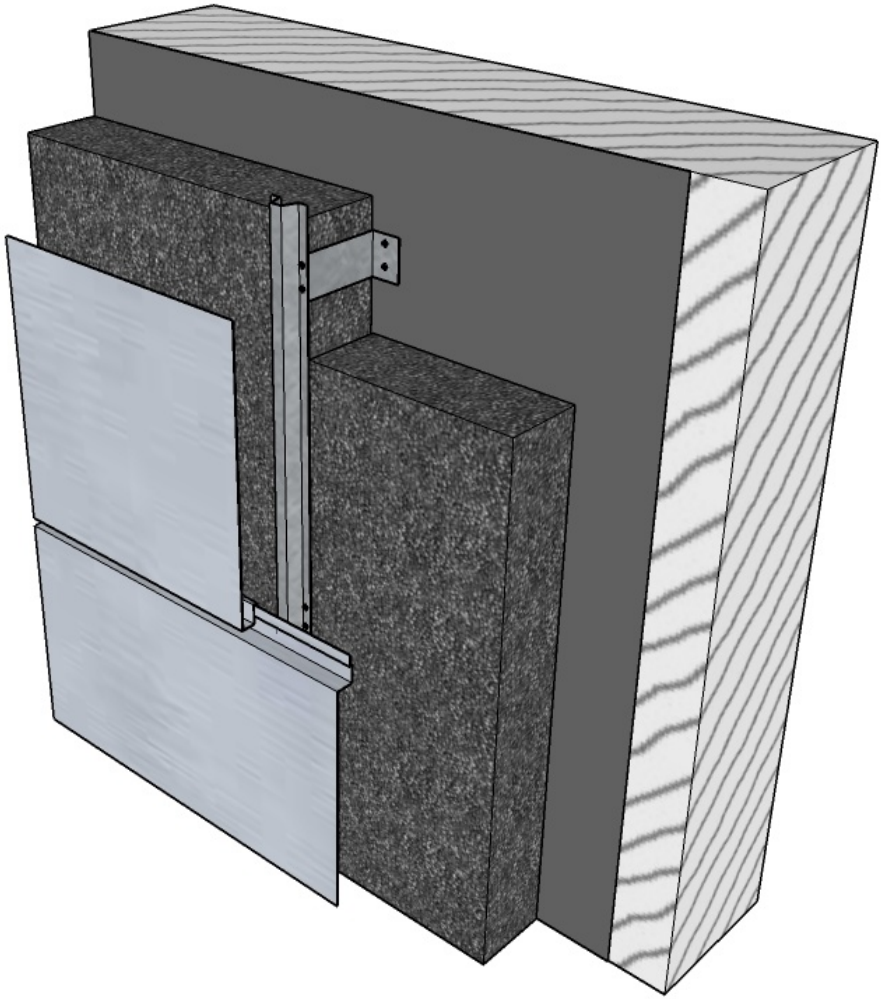
- Single “z-furring”
- Double “z-furring”



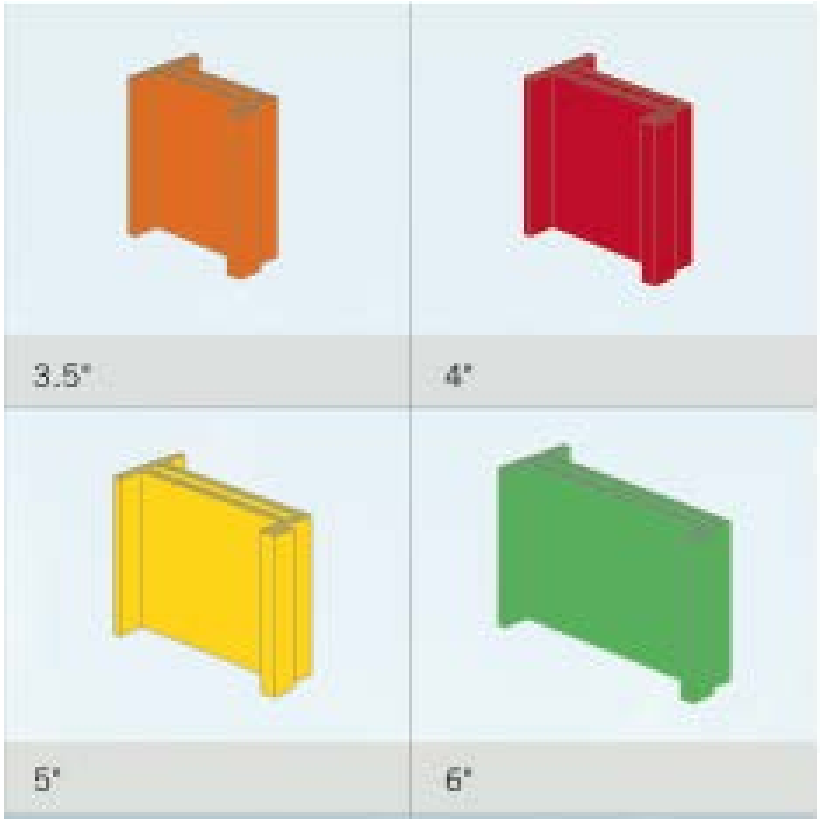


Cladding Attachment

- Single “z-furring”
- Double “z-furring”
- Clip and “z-furring” or hat channel
  - Metal clip
  - Fiberglass clip

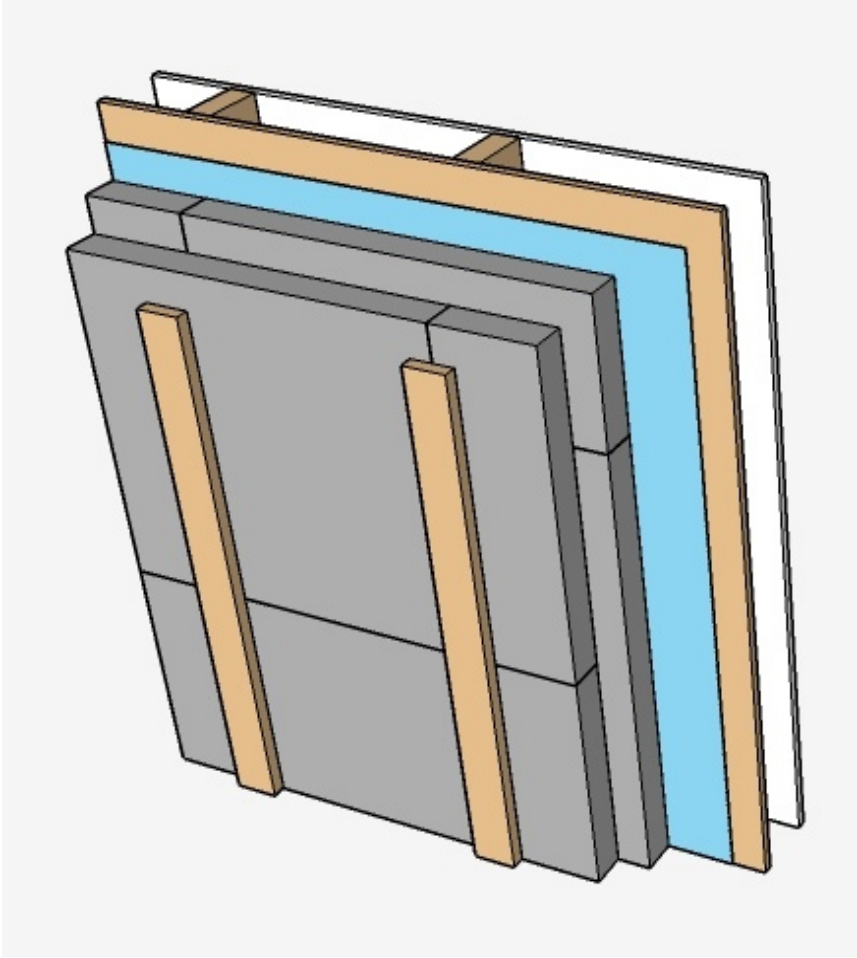


Cladding Attachment

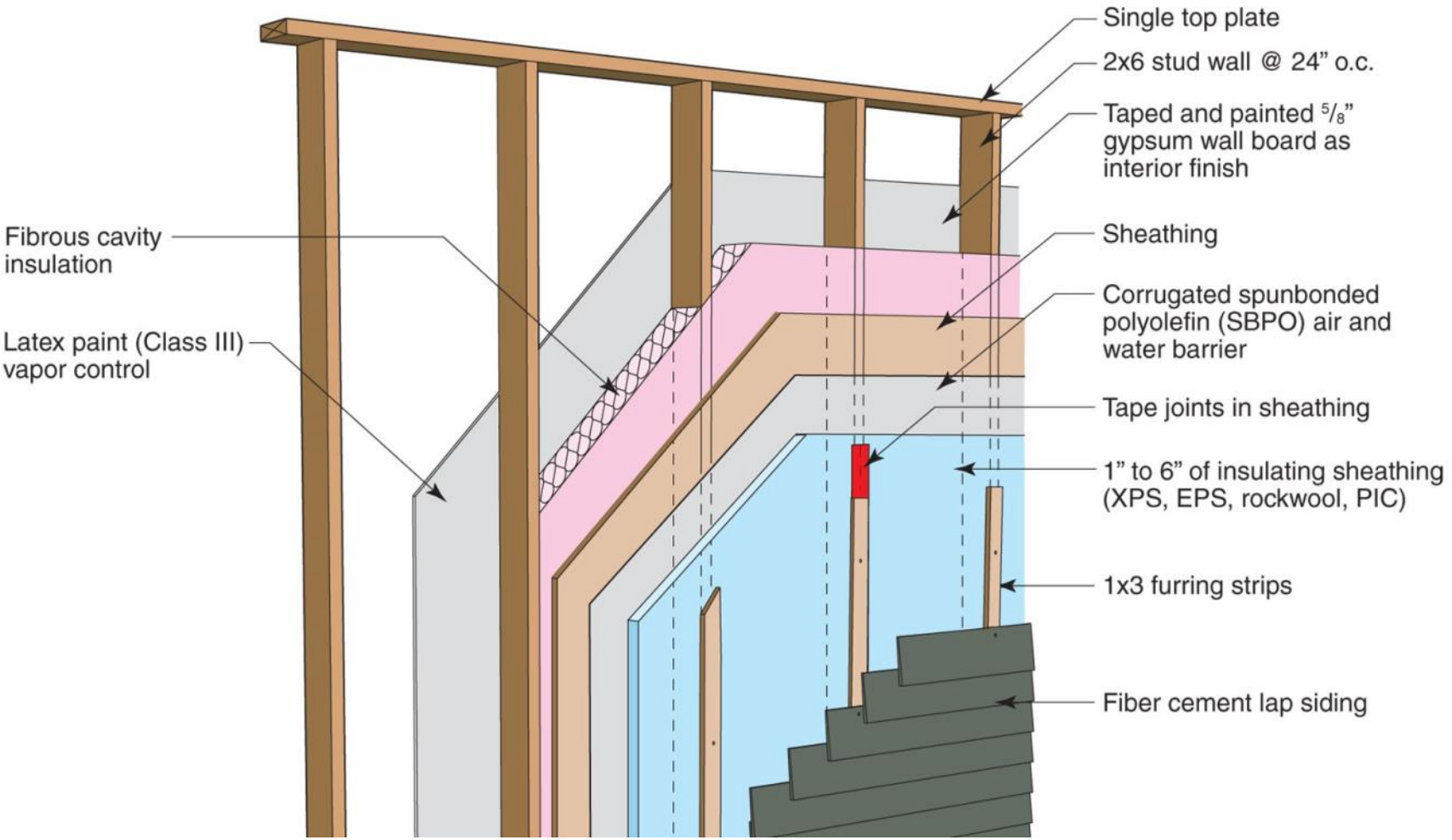


Cladding Attachment

- Single “z-furring”
- Double “z-furring”
- Clip and “z-furring” or hat channel
  - Metal clip
  - Fiberglass clip
- Attach furring directly back to structure through insulation



Cladding Attachment



Cladding Attachment

Direct Cladding Attachment Through Insulation

Direct Attachment Through Insulation

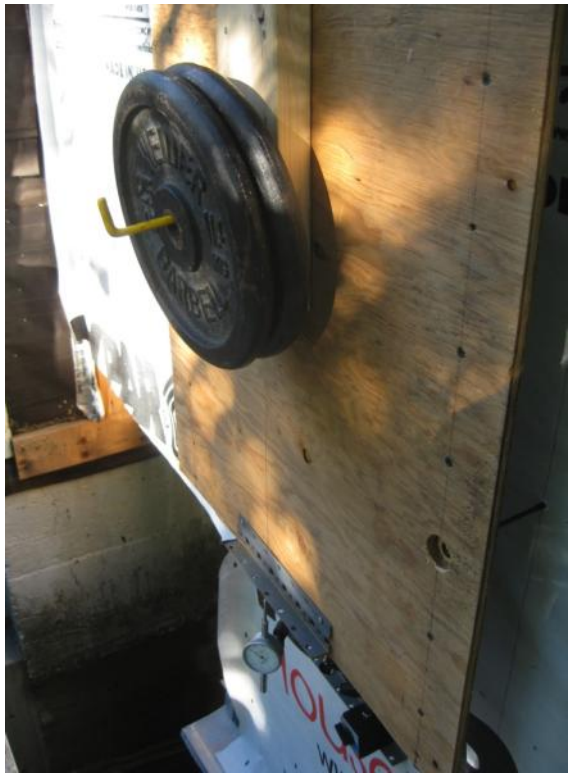
- Lots of practical experience with this approach for lightweight cladding systems over thick layers of insulation (several decades).
- Approach has demonstrated very good long term performance
- High resistance from industry

Direct Attachment Through Insulation

- “Does the insulation provide any additional capacity for the system?”
- BSC staff test

Direct Attachment Through Insulation

- System loaded with air gap between furring and wall

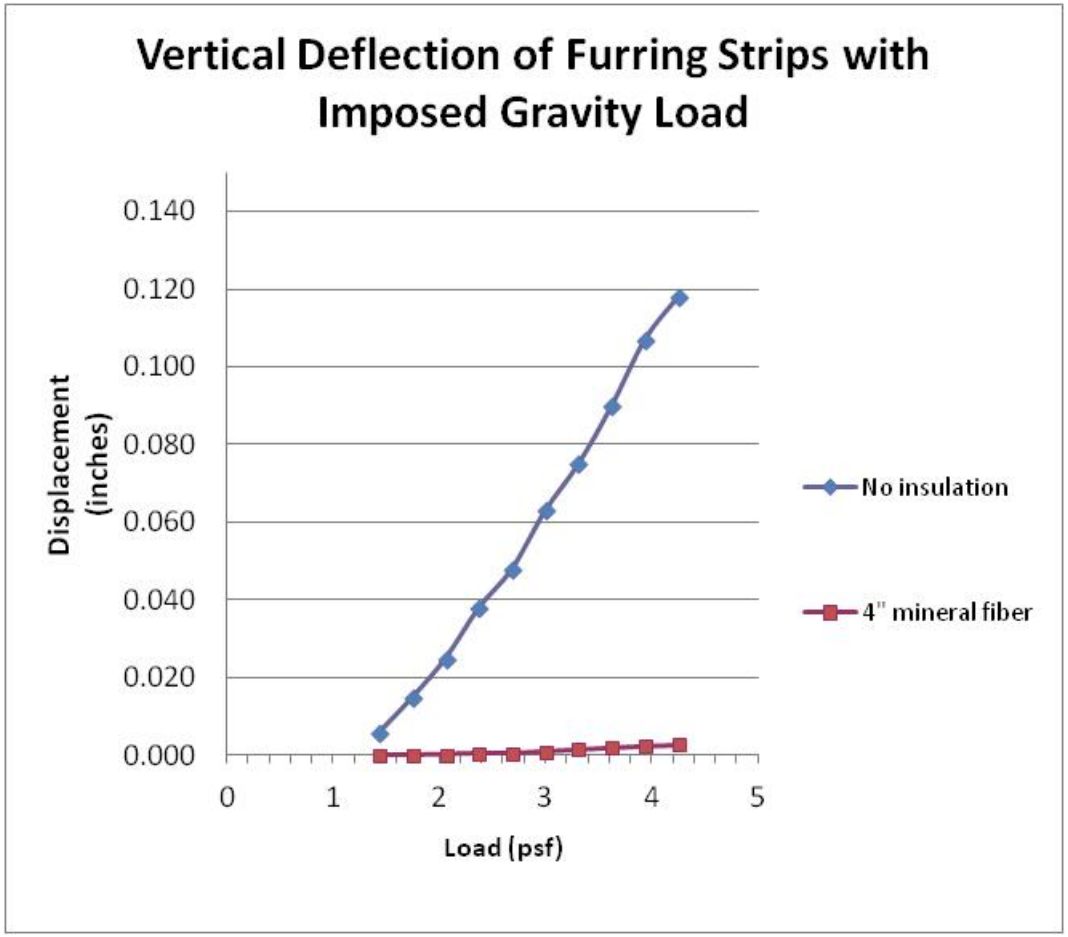


Direct Attachment Through Insulation

- System loaded with 4” of rigid mineral fiber insulation between furring and wall

Direct Attachment Through Insulation

- The answer is yes!



Direct Attachment Through Insulation

- “Does the insulation crush under load?”
- The answer is yes!...
- Loading a system until failure (500lbs to 1000lbs or more per screw fastener) will crush most rigid insulations

…..Unfortunately it is the wrong question

Direct Attachment Through Insulation

- "Does the insulation crush under a load similar to what will be imposed on it in a cladding support application?"
- The answer is no!...

Context is important

Direct Attachment Through Insulation

- Typical cladding weights (psf)

	low	high
Vinyl	0.6	1.0
wood	1.0	1.5
fiber cement	3.0	5.0
stucco	10.0	12.0
adhered stone veneers	17.0	25.0

Direct Attachment Through Insulation

- Typical weights per fastener (lbs)

fastener spacing (in)	16" x 16"	16" x 24"	24" x 24"
area/fastener (ft2)	**1.78**	**2.67**	**4**
vinyl	1.8	2.7	4.0
wood	2.7	4.0	6.0
fibercement	8.9	13.3	20.0
stucco	21.3	32.0	48.0
adhered stone veneers	44.4	66.7	100.0

Direct Attachment Through Insulation

- Acceptable deflection not ultimate capacity governs
- What is acceptable deflection?
  - Movement a cladding system can accommodate without physical damage or exceeding aesthetic tolerances
- Proposed limits
  - Lap sidings and panel cladding ~ 1/16”
  - Brittle claddings ~1/64” (after initial deflection)

TO2 Building America Research (2011)

Gravity Load Response Testing (2011)

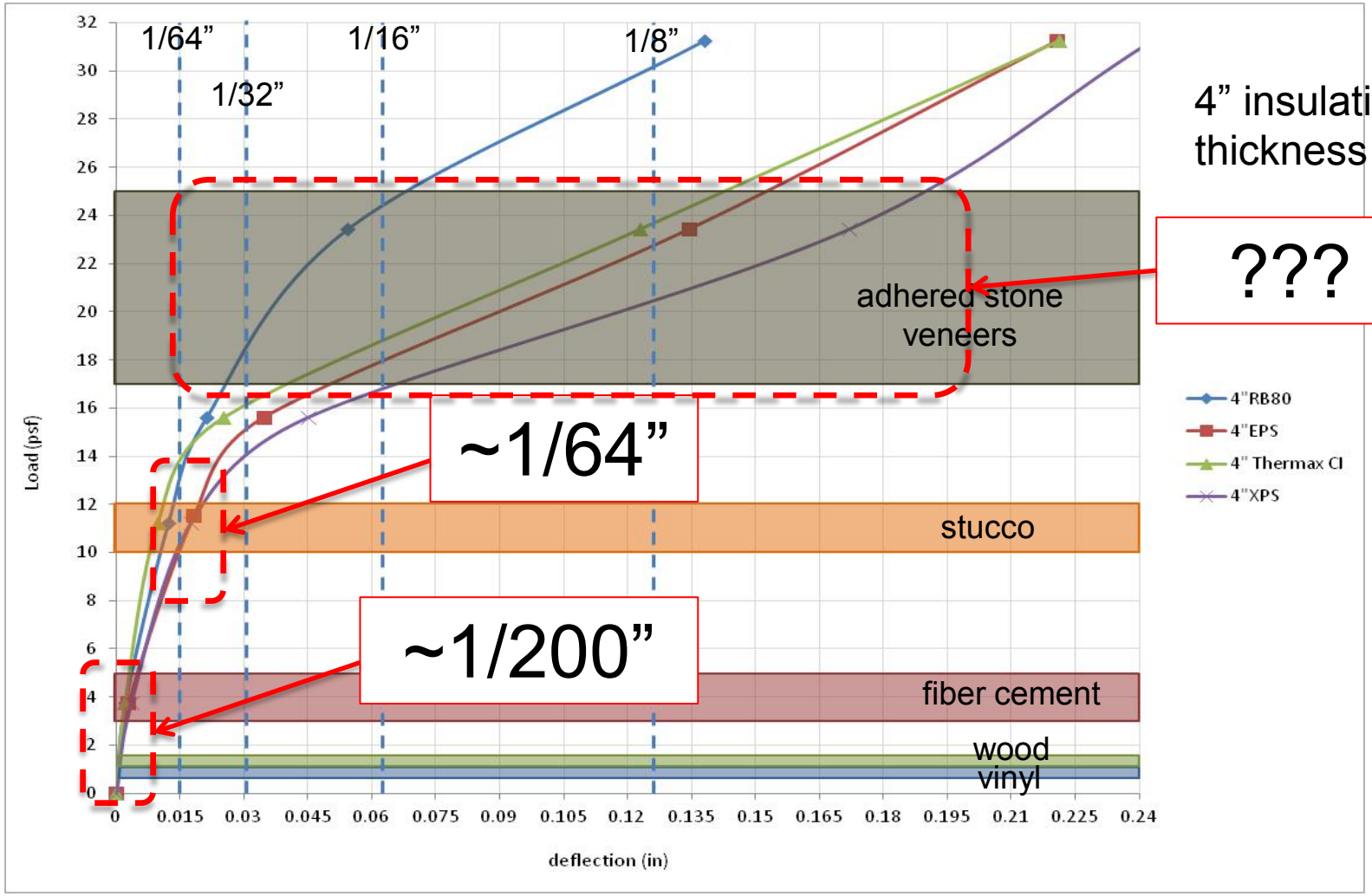
- BSC Research TO2 (DOE Building America Program)
- Short Term and Long Term Deflection Testing
- Multiple insulation types
  - EPS
  - XPS
  - Foil faced polyisocyanurate
  - Rigid mineral fiber

Gravity Load Response Testing (2011)

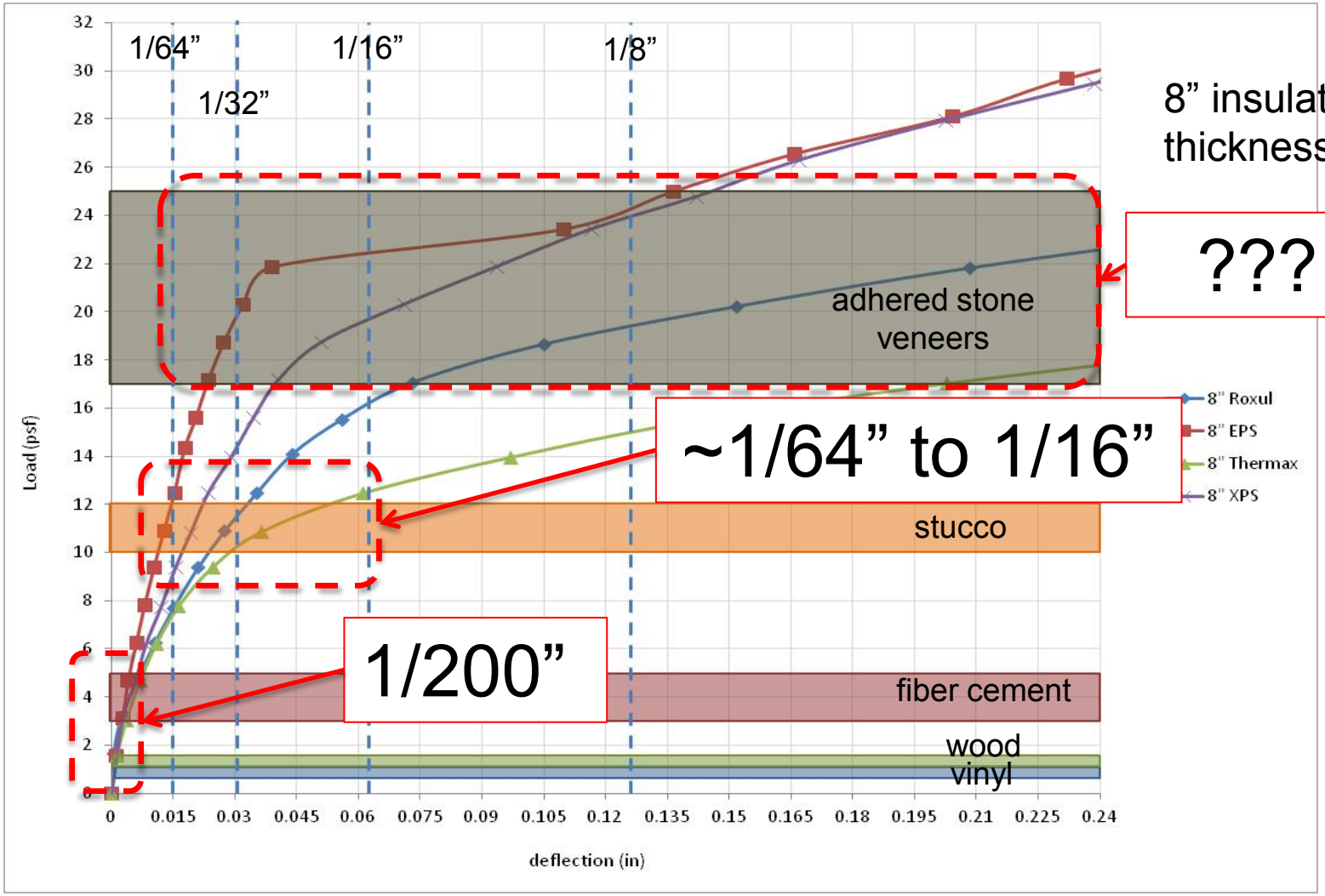
- Short term testing
- Test panels
  - 4’x8’
  - 1x3 furring spaced 24” oc
  - 16” vertical spacing of fasteners
- Multiple thicknesses
  - 4” and 8” tests

Short-term Gravity Load Response

Short-term Gravity Load Response



Short-term Gravity Load Response

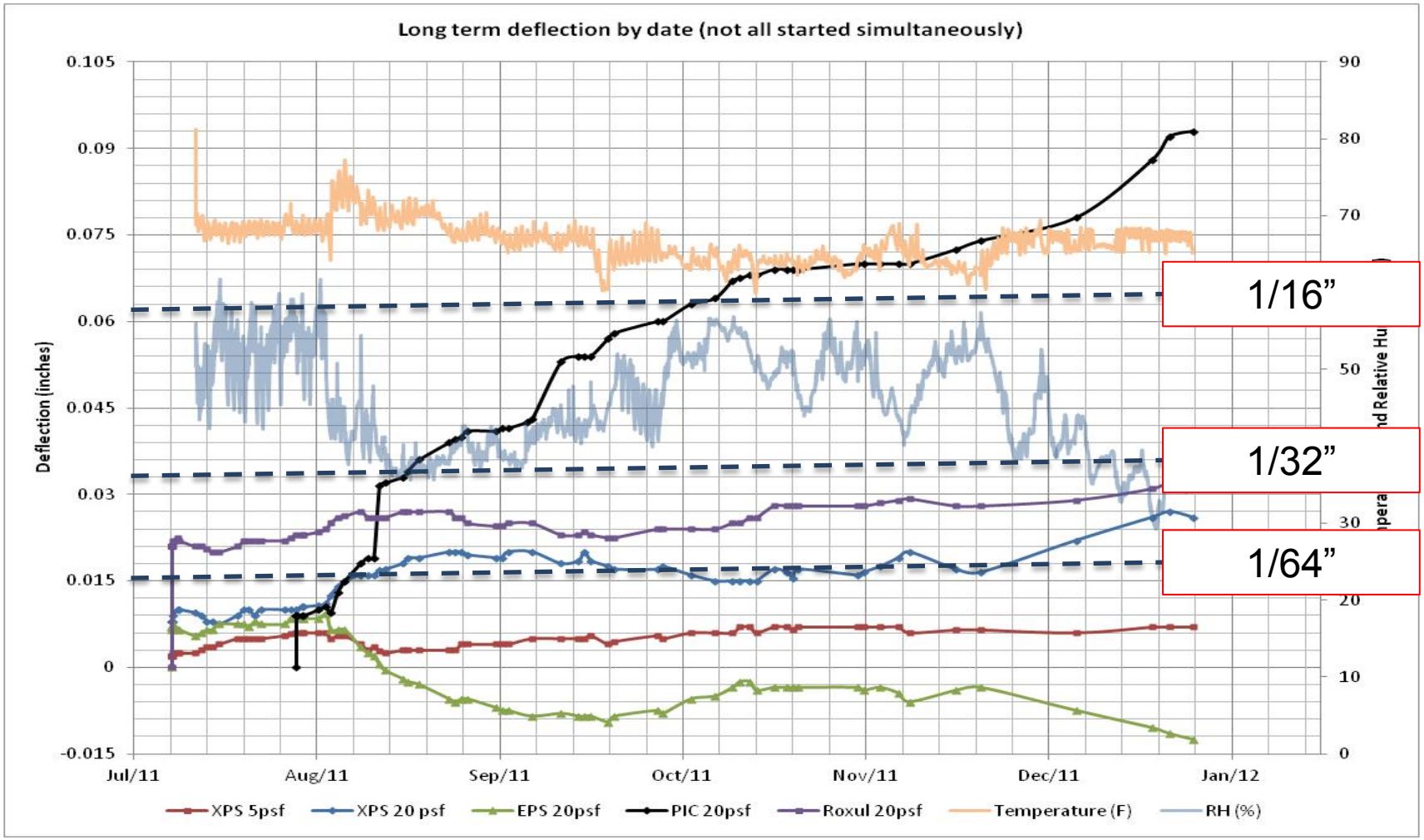


Long-term Gravity Load Response

- Long term testing
- Test panels
  - 2’x8’
  - 1x3 furring
  - 16” vertical spacing of fasteners
- Load
  - 13 psf if 24” oc
  - 20 psf if 16” oc
  - 30 lb/fastener

Long-term Gravity Load Response

Long-term Gravity Load Response



Testing Results

- Lightweight claddings (vinyl, wood, fiber cement) have very little movement both under initial loading and long term loading (~1/200”)
- For lightweight claddings deflection does not even approach proposed deflection limit (1/16”)
- Testing results in line with long history of performance of buildings constructed with this assembly

Testing Results

- Heavier brittle claddings (stucco, adhered stone veneers) initial deflection is not as important as long term deflection
- For stucco claddings (10psf), long term deflection after initial deflection is within proposed deflection limit in stable environmental conditions
- For adhered stone veneer (17psf to 25psf), capacity could be increased with increased fastener spacing.

Additional Questions

- Creep is still not well understood or quantified
- Affected by multiple factors
  - Expansion and contraction of wood
  - Expansion and contraction of insulation
  - Relaxation of wood fibers
  - Plastic deformation of insulation
- Many of these are affected by temperature and relative humidity
- More research is needed to examine the performance of these systems in exposed environments

Additional Questions

- The exact mechanisms of the load deflection resistance are not well quantified
- Discrete load components are theorized but have not been measured
- Important to understand factors that affect the development of system capacity to examine means to design the attachment systems

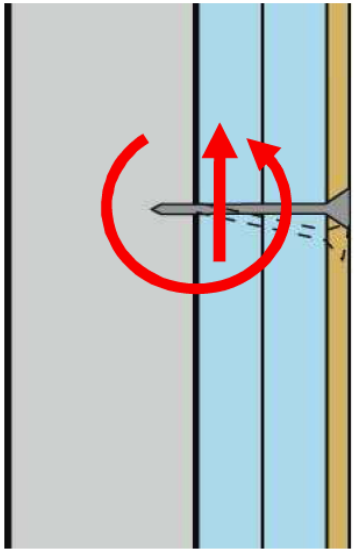
TO3 Building America Research (2012)

Gravity Load Response Testing (2012)

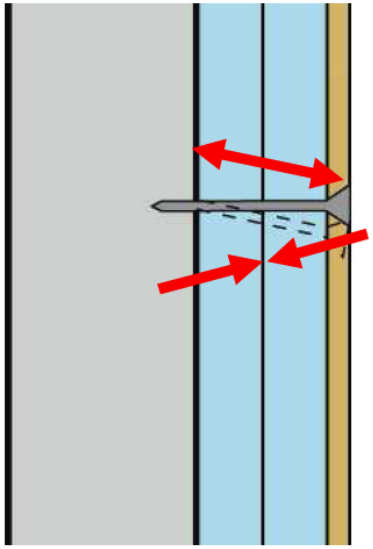
- BSC Research TO3 (DOE Building America Program)
- Discrete Load Component Testing
- Long Term Deflection Testing in Exposed Environment
- Multiple insulation types
  - EPS
  - XPS
  - Foil faced polyisocyanurate
  - Rigid mineral fiber

Gravity Load Response Testing (2012)

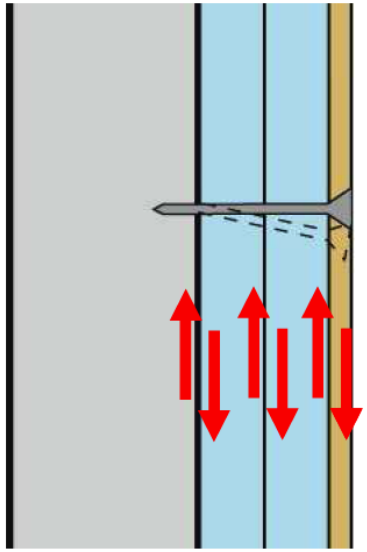
- Discrete Load Components



Shear and rotational resistance provided by fastener to wood connections



Rotational resistance provided by tension in fastener and compression of the insulation



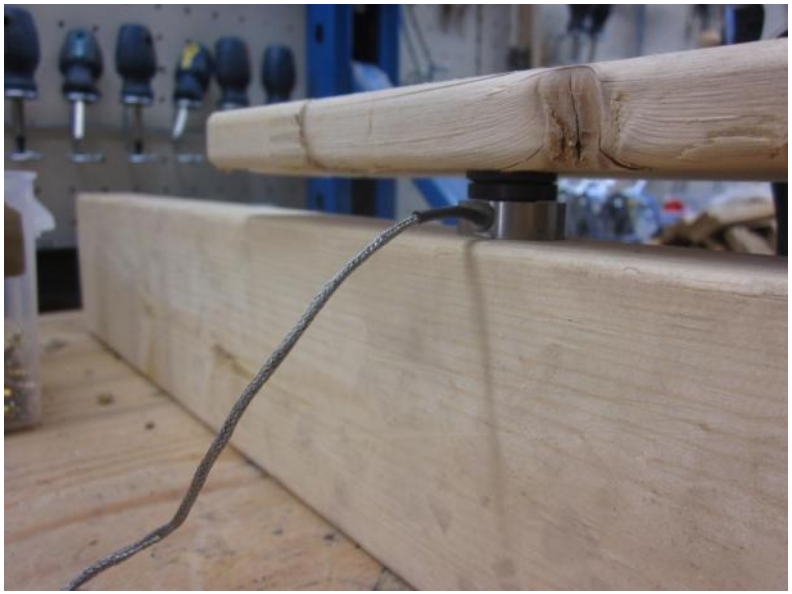
Vertical movement resistance provided by friction between layers

Discrete Load Component Testing

- Series of tests to measure material properties
  - Coefficients of friction
  - Compression modulus of insulation
- Small scale test to try to isolate the discrete functions
  - Screw bending/wood bearing
  - Strut and tie model
  - Friction between layers
    - Due to pre-compression (clamping) forces
    - Due to rotational forces

Discrete Load Component Testing

- Pre-compression (clamping) forces
  - Forces imposed on the system by tightening of the screw fasteners that hold the wood furring in place
  - Tested using common #10 Wood Screws



Discrete Load Component Testing

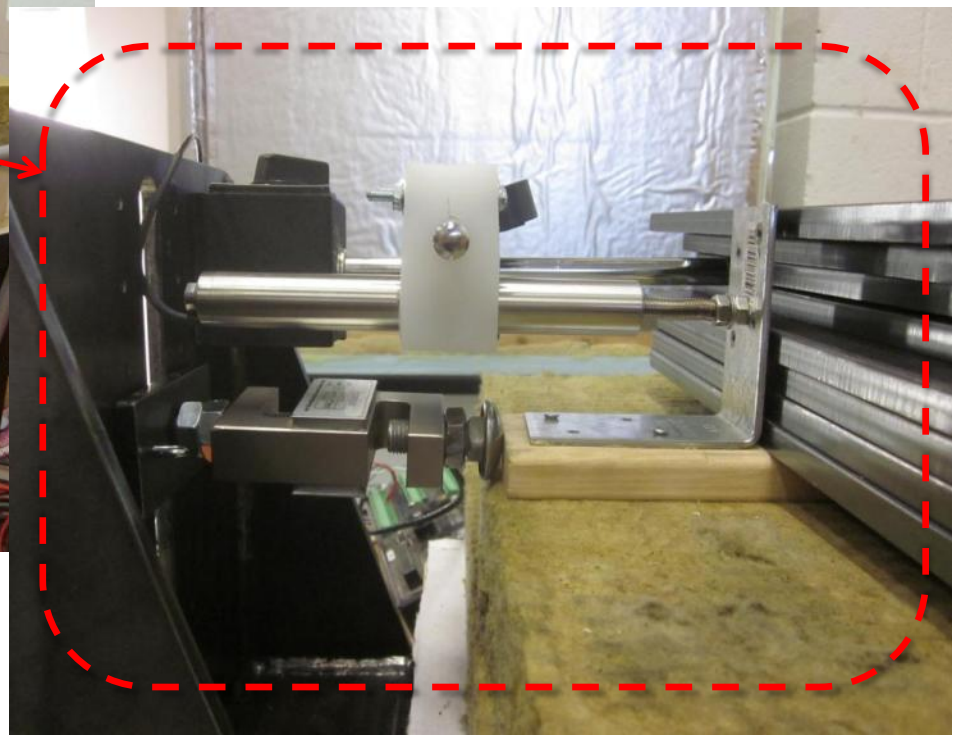
- Pre-compression (clamping) forces
  - Failure mechanism – head pull through of fastener through the furring
  - Preliminary results indicate pretty consistent force magnitudes
    - ~ 150 lbs per fastener with screw head flush with furring surface
    - ~ 180 lbs per fastener with screw over driven
  - Additional testing to be completed to examine relaxation in load over time

Discrete Load Component Testing

- Small Scale Discrete System Tests
  - Custom built test apparatus
  - Intent to evaluate individual force resistance components
    - Screw bending/wood bearing
    - Strut and tie model
    - Friction between layers

Discrete Load Component Testing

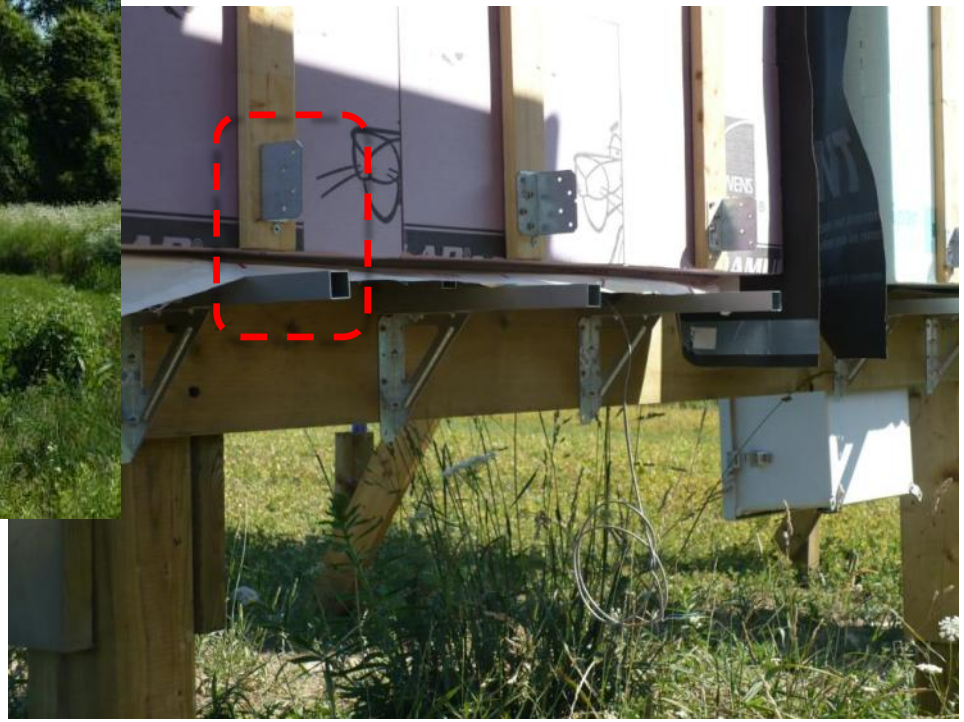
Discrete Load Component Testing



Climate Exposure

- Full Scale Wall Assemblies
- Loaded to three representative cladding weights
  - Fiber cement
  - Stucco
  - Cultured stone
- Deflection measured over the course of the year

Climate Exposure



Climate Exposure

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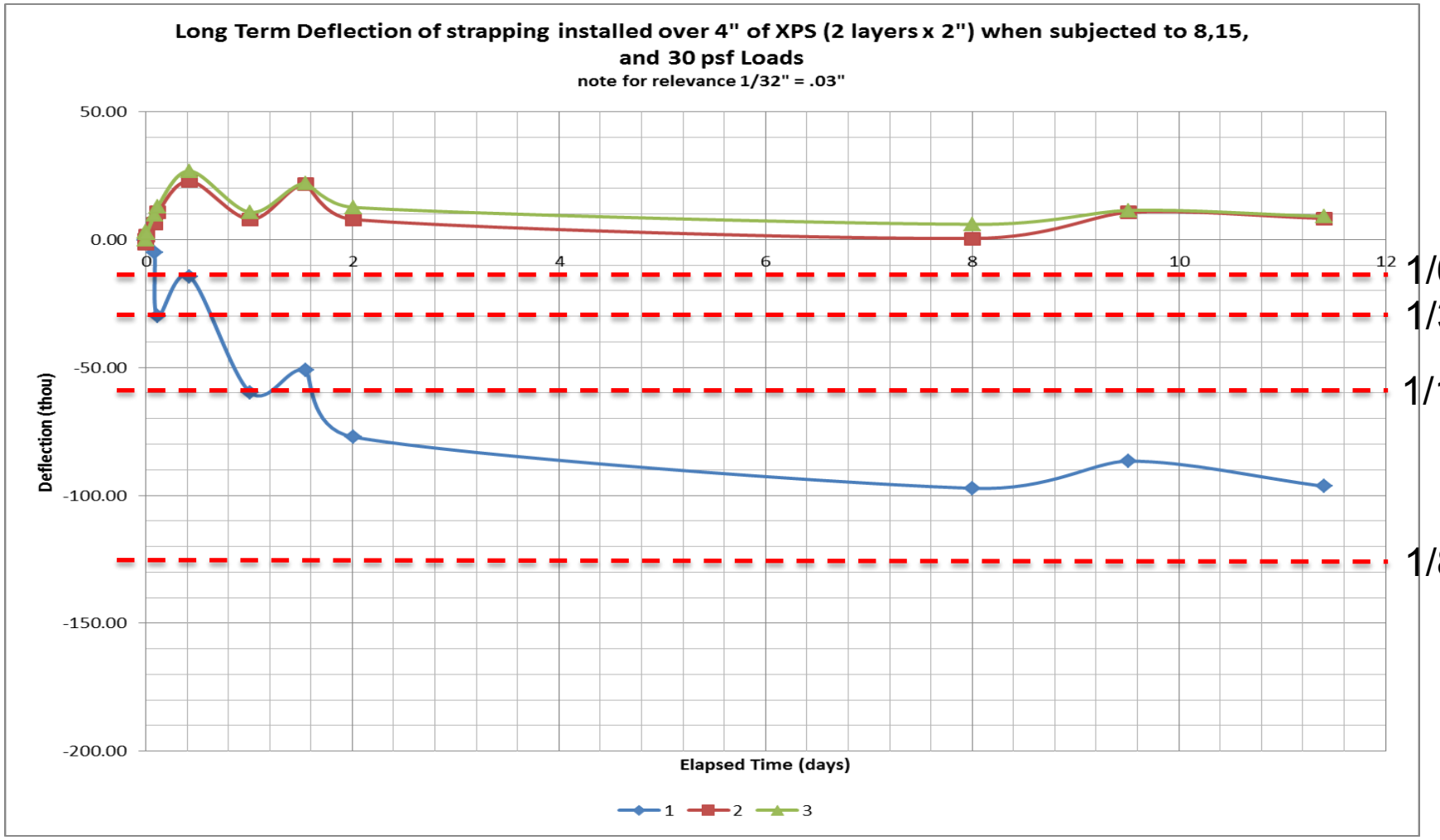
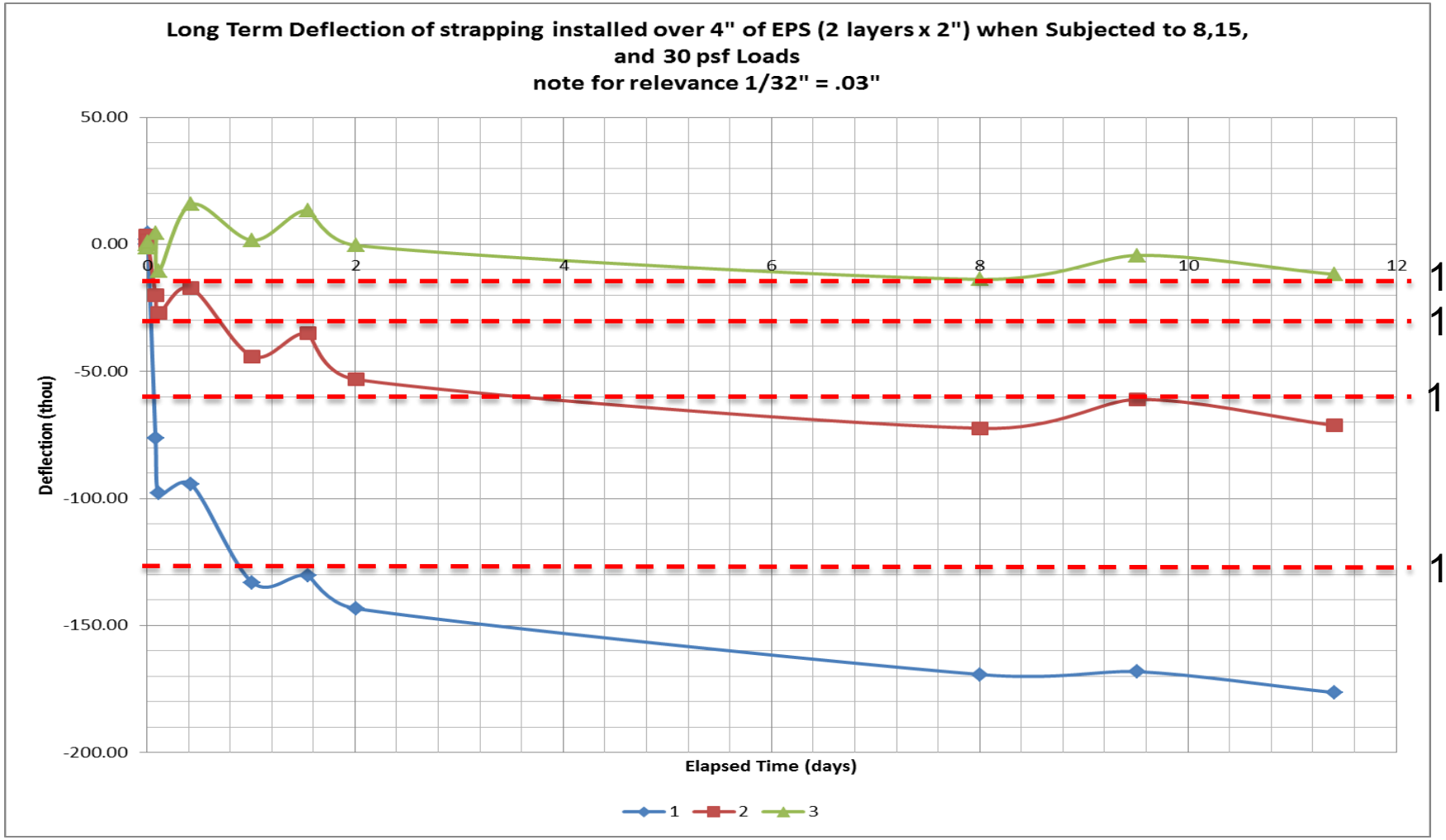


Climate Exposure



Testing Results

- Testing is still underway
- Results have not been fully analyzed

Thank you for your time!
Any Questions?